LOW COST GEAR FUEL PUMP

Cross Reference to Related Applications

[0001] This application claims priority from U.S. Provisional Patent Application Serial No. 60/544,582 filed February 13, 2004 and is incorporated herein by reference.

Background of the Invention

[0002] This present invention relates generally to gear pumps. More particularly, it relates to an improved bearing and gear assembly construction, particularly one used as a fuel pump, and methods of making the same.

[0003] A typical gear fuel pump is a fixed displacement pumping device. It receives fuel from the fuel tank, pressurizes the fuel, and delivers the fuel at a higher pressure to the fuel nozzle via a fuel control for engine combustion. The gear pump generally includes a housing, such as an aluminum housing, having an interior pump chamber defined by parallel, intersecting, cylindrical bores. First and second gears, usually of similar configuration, are disposed in respective bores and the gears mesh with each other in the area of intersection of the bores inside the housing. A first or drive gear has a splined drive shaft and as it rotates, the first gear drives a second gear, commonly called the driven gear. As the gears rotate within the housing, fluid is transferred from an inlet to an outlet of the pump. The gears are highly stressed at high pressures and high loads. Gears of either spur or helical configuration can be used; although spur gears are most common. The gears are driven to unmesh adjacent the inlet and convey the fluid around the periphery of the bores to the region where the gears mesh. The meshing of the gears forces the fluid out of the pump chamber where it exits the pump housing through the outlet.

[0004] Since the pressure of the fluid being pumped is greater at the outlet than at the inlet during pump operation, the pressure differential can cause leakage flow from the outlet to the inlet across the interfaces of the various components. This leakage flow lowers the efficiency of the pump. In some instances, there can be substantial variations in the leakage flow from one identically made pump to another. Since the volume pumped is a direct function of the volume displaced by the meshing gears, variation in depth of mesh gears will also greatly affect capacity. Thus, it is important to provide precise alignment and meshing of the gears in order to improve pump efficiency.

[0005] Typically, four separate bearings are disposed in the bores and journal or support portions of the gear shafts. The bearings usually have a generally cylindrical exterior configuration with facing and engaging flats along one portion of the periphery that align with region in which the gears mesh. The bearings are sized to fit the pump chamber. In the usual case, the bearings are manufactured paying close heed to the design dimension between the center of the flat and the diametrically opposite side of the otherwise cylindrical bearing. In order to minimize leakage paths, such bearings are made to form a tight fit within respective bores in the pump and not infrequently, due to tolerance variations, good fitting cannot always be attained. Thus, it has been customary to, during the assembly process, shave material off of the flats of one or more of the bearings in the hope that a precise fit can be achieved. Indeed, the bearings are designed to be shaved so as to accommodate tolerance variation while attempting to maintain a tight fit.

[0006] However, in the shaving process, parallelism of the face of the flat to the axial center line of the bearing may be lost, creating a leakage path. Alternatively, the flatness of the face can be lost during the shaving process, again creating a leakage path across the flats. The shaving process may also result in a loss of squareness or perpendicularity of the face of the flat to the end of the bearing which in turn may not seal properly against the housing end wall, which may prevent the bearing from moving properly in response to shaft deflection during operation, or may misalign the shafts. Shaving may also result in a changed depth of mesh of the gears journalled by the bearings, thus altering the pump's capacity.

[0007] Another substantial factor resulting in the differing capacities in otherwise identical pumps is the fact that conventionally, each splined drive shaft and corresponding gear are manufactured one-piece bar stock driven gears where the bar portion (i.e. drive shaft) and gear are formed as a single, one-piece unit. As such, opposing end portions of the drive shaft are separately manufactured and may result in differing diameters of the opposing end portions which impacts mating with the bearings.

[0008] Commonly assigned U.S. Patent No. 6,042,352 is directed to a gear pump of the type for which the improved gear fuel pump was developed. Other existing gear pump designs are known in the art, including the following: U.S. Pat. Nos. 4,682,938; 4,193,745; 4,097,206; 3,003,426; 2,981,200; and 2,774,309.

[0009] In light of the foregoing, it is evident that there is a need for an improved gear pump that provides a solution to one or more of the deficiencies in the art. It is still more clear that an improved gear pump, such as a fuel pump, providing a solution to each of the needs inadequately addressed by the prior art while providing a number of heretofore unrealized advantages thereover would represent a marked advance in the art.

Brief Description of the Invention

[0010] A new and improved gear fuel pump assembly is provided.

[0011] More particularly, and according to one embodiment of the present invention, the gear pump comprises a housing including an interior pumping chamber and an inlet and outlet in spaced relation that each communicate with the chamber. A pair of rotating gears is located in the chamber, each gear being fixedly secured on a respective shaft having an axis of rotation. The gear teeth mesh to pressurize fluid pumped through the housing. A pair of one-piece bearings is located in the chamber on opposite ends of the gears and journal one of first and second end portions of each shaft. The one-piece bearings provide precise alignment of the first and second the shafts and maintain the shafts in parallel relation.

[0012] Preferably, the gears are formed from powder metal and secured on constant diameter shafts. Each gear is keyed to one of the shafts so as to rotate therewith, and the dimensional tolerance between the shaft and gear provides for proper meshing of the gears if there is any slight misalignment.

[0013] According to another embodiment of the present invention, a method of assembling a gear pump is provided. The method comprises the steps of providing first and second shafts having substantially constant diameters along their lengths. A gear is advanced over each shaft and secured to each shaft. A one-piece bearing is then mounted on the shafts. The bearing and shafts with gears mounted thereon are installed into a housing of a gear pump.

[0014] According to one aspect of the present invention, the one piece bearings and the gears are made from powder metal. By using powder metal technology, the one-piece bearings and gears can be formed without the requirement of extensive additional machining.

[0015] A primary benefit of the present invention resides in the ability to provide homogenous one-piece bearings which have a higher accuracy in alignment compared to conventional bearings.

[0016] Another benefit of the present invention resides in the ability to provide powder metal components for a gear pump which last as long or longer than components formed from conventional materials.

[0017] Still another benefit resides in the precise alignment associated with the use of one-piece bearings.

[0018] A further benefit resides in the substantial savings associated with powder metal components by reducing the extensive additional manufacturing steps associated with conventional bearings, gears and shafts.

[0019] Still other benefits and aspects of the invention will become apparent from a reading and understanding of the detailed description of the preferred embodiments hereinbelow.

Brief Description of the Drawings

[0020] The present invention may take physical form in certain parts and arrangements of parts, preferred embodiments of which will be described in detail in this specification and illustrated in the accompanying drawings which form a part of the invention.

[0021] FIGURE 1 is an exploded perspective view of a conventional gear pump assembly.

[0022] FIGURE 2 is a top plan view, partially broken away, of a cover plate and housing of the conventional gear pump assembly of FIGURE 1.

[0023] FIGURE 3 is a sectional view taken approximately along line 3--3 in FIGURE 2.

[0024] FIGURE 4 is an exploded perspective view of a gear pump assembly according to the present invention.

[0025] FIGURE 5 is a top plan view, partially broken away, of a cover plate and housing of the gear pump assembly of FIGURE 4.

[0026] FIGURE 6 is a sectional view taken approximately along line 6--6 in FIGURE 5.

[0027] FIGURE 7 is a bottom plan view of a one-piece first bearing of the gear pump assembly of FIGURE 4.

[0028] FIGURE 8 is a sectional view taken approximately along line 7–7 in FIGURE 7 showing the first bearing.

[0029] FIGURE 9 is a top plan view of the first bearing of the gear pump assembly of FIGURE 4.

[0030] FIGURE 10 is a sectional view taken approximately along line 10–10 in FIGURE 9.

[0031] FIGURE 11 is a top plan view of a one-piece second bearing of the gear pump assembly of FIGURE 4.

[0032] FIGURE 12 is a sectional view taken approximately along line 12–12 in FIGURE 11 showing the second bearing.

[0033] FIGURE 13 is a bottom plan view of the second bearing of the gear pump assembly of FIGURE 4.

[0034] FIGURE 14 is a sectional view taken approximately along line 14–14 in FIGURE 13.

[0035] FIGURE 15 is a plan view of a first shaft of the gear pump assembly of FIGURE 4.

[0036] FIGURE 16 is a sectional view taken approximately along line 16–16 in FIGURE 15.

[0037] FIGURE 17 is a plan view of a second shaft of the gear pump assembly of FIGURE 4.

[0038] FIGURE 18 is a side elevational view of the second shaft of FIGURE 17.

[0039] FIGURE 19 is a sectional view taken approximately along line 19–19 in FIGURE 18.

[0040] FIGURE 20 is a top plan view of a gear of the gear pump assembly of FIGURE 4.

[0041] FIGURE 21 is a sectional view taken approximately along line 21–21 in FIGURE 20.

Detailed Description of the Invention

[0042] It should, of course, be understood that the description and drawings herein are merely illustrative and that various modifications and changes can be made in the structures disclosed without departing from the spirit of the invention. Like numerals refer to like parts throughout the several views.

[0043] With reference to FIGURE 1, a conventional gear pump assembly **GP** typically includes a housing **10**, generally made from aluminum, having end flanges **12** and **14** and an end plate or lid **16** for sealing the housing. End flange **12** includes a plurality of apertures **18** and the lid includes corresponding apertures **20** dimensioned to receive conventional fasteners **F** which secure the lid to the housing. As shown in FIGURES 1 and 2, the end flange **12** and the lid **16** are generally polygonal in cross-section, although, it should be appreciated by one skilled in the art that the end flange and lid can have other configurations depending on the use of the gear pump and/or the environment in which the pump is used. The housing further includes a recess **22** which receives a seal **24**. End flange **14** also includes a plurality of mounting apertures **26** for mounting the gear pump **GP** to any source of rotational energy (not shown).

[0044] With reference to FIGURE 2, the housing **10** includes a chamber **30**, defined by two parallel, intersecting, cylindrical bores **32** and **34**. The housing **10** has an inlet **40** and an outlet **42**. As shown in FIGURE 1, the gear pump **GP** further includes first and second gears **50**, **52** disposed within the bores **32** and **34**, respectively, so as to be meshed generally in the region of a dotted line designated **54** in FIGURE 3. The gear **50** is integrally formed with a hollow drive shaft or journal **60** while the gear **52** is integrally formed with a hollow driven shaft or journal **62**. Typically, the shaft and gear are formed from stock material and machined to the desired diameter of the shaft and the gear detail. As will be appreciated, a substantial amount of stock material is removed in this conventional manufacturing operation. Moreover, as noted in the Background, there are problems associated with that conventional arrangement.

[0045] The driven shaft **62** includes a splined internal surface (not shown) which is engaged by a splined end portion of a rotational shaft **S** which is connected to the source of rotational energy. The rotational shaft **S** extends through an opening (not shown) in the housing. An o-ring **68** and a shaft seal **70** are provided about the opening to prevent gear pump external leakage. A seal **72** is normally coupled to the drive shaft.

[0046] Within the housing **10**, both of the shafts **60**, **62** have end portions **76** which are supported or journalled in respective first and second bearings **80**, **82**. The bearings **80**, **82** are separately formed and generally cylindrical about the rotational axis of the shafts defined by cylindrical openings **84**, **86**. Each of the bearings is also provided with respective flats **88**, **90** on a portion of the circumference immediately adjacent the point **54** where the gears **50**, **52** mesh. Each flat **88** on adjacent bearings **80** includes a hole or recess **92**. The flats **88** face each other and engaged one another

by a pin **94** received in the holes. Similarly, each flat **90** on adjacent bearings **82** include a hole or recess **96** that receive a pin **98**. The flats **88** and **90** are intended to be defined by planes parallel to the center line of the openings **84, 86**.

[0047] Generally, the bearings are longitudinally fixed in the cylindrical bores **32** and **34** of the housing **10**. However, a bottom surface **100** of each bearing **82** includes a flange **102** having a plurality of openings (not shown) for receiving individual springs **104**. As such, the pressurized bearings are urged or biased in a longitudinal direction along the end portions **76** of the shafts **60, 62** in the cylindrical bores.

[0048] The fuel is pumped from the low pressure inlet side of the bearings **82** to the high pressure discharge side of the bearings. The gears **50, 52**, which are longitudinally received between the bearings **80, 82**, rotate about respective, parallel axes, and mesh together. Fluid is thus moved from the inlet around the outside of the gears **50, 52** to the outlet in a manner well known in the art.

[0049] As shown in FIGURES 1 and 2, the bearing arrangement and the cylindrical bores **32** and **34** of the housing **10** have a figure eight configuration. In the manufacture of the prior art bearings **80** and **82**, the controlled tolerance is the distance from the flat **88** and **90** to a diametrically opposite point on the periphery of the bearing. As described above, the flats **88** and **90** are typically shaved so as to allow the bearings **80** and **82** to be fitted to in the gear pump housing **10**. As such, the controlled tolerance is lost to some degree during the shaving process. Because the flats on bearings utilized in prior art gear pumps require shaving during assembly, the loss of parallelism of the flat to the center line of the bearing, the loss of flatness, or the loss of squareness of the flats **88.90** relative to respective top surfaces **110, 112** and bottom surfaces **114, 100** of the bearings **80, 82** occurs. As a result, the gear pump **GP** may experience leakage or be less efficient than desired.

[0050] As briefly stated above, the gears **50, 52** are integrally formed with the respective shafts **60, 62**. Each shaft and corresponding gear are manufactured from a one-piece bar stock where the opposing end portions **76** of the shaft and the gear are formed as a single unit. As such, the opposing end portions of the shaft are separately formed which may result in differing diameters of the opposing end portions. To correct this dimensional difference, the diameter of the larger opposing end portion is typically ground down to match the diameter of the other end portion. However, this grinding process may also result in a loss of squareness or perpendicularity of the shafts **60** and **62** to the integral gears **50** and **52**. This can effect the meshing of the gears, and since

the volume pumped is a direct function of the volume displaced by the meshing gears, can affect the capacity of the gear pump.

[0051] With reference now to FIGURE 4, a gear pump according to the present invention is shown. Since much of the structure and function is substantially identical, reference numerals with a single primed suffix (') refer to like components (e.g., housing **10** is referred to by reference numeral **10'**), and new numerals identify new components. Likewise, description of components that remain unchanged is not necessary.

[0052] The gear pump assembly **GP'** shown in FIGURES 4-6 includes the housing **10'** having a chamber **200**, defining a single cylindrical bore **202**. The housing **10'** receives a pair of bearings **204**, **206**, each bearing being a one-piece bearing formed from powder metal. That is, the bearings are substantially homogenous components that do not have joint lines, i.e., they are continuous, when compared to the two-piece bearing assemblies of the prior art. Each bearing preferably has a generally oblong cross-section. It will be appreciated that the periphery of each bearing mates with the similarly dimensioned bore **204** of the housing **10'**. However, it should be appreciated by one skilled in the art that the bearings and corresponding bore can have other contours which would allow each bearing to be closely received within the chamber **200** of housing **10'**.

[0053] With reference to FIGURES 8 through 10, the unitary bearing **204**, which is generally longitudinally fixed in the housing, includes a first or top surface **220**, a second or bottom surface **222**, and a pair of openings **224**, **226** having center axes coincident with axes of rotation of shafts or journals **230**, **232**. The bearing further includes first and second elongated sides **236**, **238**. The first elongated side is generally parallel to the second elongated side, and in the preferred arrangement the elongated sides are generally planar. Opposing ends **240**, **242** have an arcuate contour, although as stated above, the ends can have other configurations without departing from the scope and intent of the present invention.

[0054] With continued reference to FIGURE 7, the bottom surface **222** of the bearing **210** includes a dam **250**, an inlet face relief **252**, and a discharge face relief **254**. Thus, the bearing dam **250** is located between the inlet face relief and the discharge face relief. The bearing dam wall forms a sealed dam area between an inlet side **256** and an outlet side **258**, thus resulting in a low-pressure area on the inlet side **40'** and high-pressure area on the outlet side **42'** of the gear pump **GP'**. The bearing further includes

a bleed hole **260** for bearing lubrication drain. As shown in FIGURE 10, the bleed hole has a substantially constant diameter along its length and intersects the dam area **250** in a perpendicular fashion.

[0055] With reference to FIGURES 11-14, the unitary bearing **212** includes a first or top surface **270**, a second or bottom surface **272**, and a pair of openings **274, 276** having center axes coincident with the center axes of the openings **224, 226** of the bearing **210** and the axes of rotation of the shafts **230, 232**. Similar to the bearing **210**, the bearing **212** further includes generally parallel first and second elongated sides **280, 282** and a pair of arcuate ends **240** and **242**.

[0056] Similar to the features of the bottom surface **222** of the bearing **210**, the top surface **270** of the bearing **212** includes a dam **290**, an inlet face relief **292**, and a discharge face relief **294**, the bearing dam wall forming a sealed dam area between an inlet side **296** and an outlet side **298**, thus also resulting in a low-pressure area on the inlet side **40'** and high-pressure area on the outlet side **42'** of the gear pump **GP'**. The bearing further includes a blind hole **300** for the retention of an energized spring **302**.

[0057] As seen in FIGURE 14, the bottom surface **272** of the bearing **212** includes a flange **310**. A seal **312** can be provided about the flange.

[0058] A pair of gears **330, 332** are longitudinally received on the shafts **230, 232** between the bearings **210, 212** (FIGURE 4). With reference to FIGURES 15 through 19, each shaft **230, 232** includes an axial recess **340** and first and second spaced, circumferential grooves **342, 344** extending radially inward from the outer periphery **346** of each shaft for receiving retaining rings or snap rings **350** (FIGURE 4). The snap rings fixedly secure the gears **330, 332** on the shafts **230, 232** and preclude longitudinal movement of the gears relative to the respective shaft.

[0059] Each shaft **230, 232** is generally hollow and has a substantially constant diameter along its lengths. As shown in FIGURE 16, shaft **232** also has a constant inner diameter. As shown in FIGURES 18 and 19, a portion **352** of an inner surface **350** of the drive shaft **230** is splined. The splined portion is engaged by a splined portion of a rotational shaft **S'** which is connected to a source of rotational energy. The rotational shaft **S'** extends through an opening (not shown) in the housing.

[0060] The shafts **230** and **232** are formed by conventional metal manufacturing. Each gear **330** and **332** (FIGURES 20-21) on the other hand is manufactured from powdered metal and includes an opening **360** adapted for receipt over one of the shafts **230, 232**. The dimensional tolerance between the outer diameter of the shaft and the

diameter of opening **360** of the gear provides some self alignment of the teeth **362** of the gears as the gears mesh if the gears/shafts are not precisely aligned. Each gear is secured generally perpendicular on the respective shaft. Each gear further includes an axial groove **364**. The axial recess **340** of the shafts and the axial groove **364** of the gear are dimensioned to receive a pin **370** that fixes or keys the gear to the shaft.

[0061] Generally, to assemble the gear pump **GP'**, a first snap ring **350** is secured in one of the first and second grooves **342, 344** of the shafts **230, 232**. The snap ring prevents axial movement of the gears on the shafts. The pin **370** is placed in the axial recess **340**. The gears **330, 332** are then advanced over each shaft in such a manner that the axial groove is aligned with the pin and the axial recess. Thus, the axial recess and groove together form a housing for the pin, the pin preventing rotation of the gears on the respective shafts. A second snap ring **350** is secured in the other groove thereby longitudinally or axially securing the gear to each shaft. The one-piece continuous bearing **212** is then installed in the chamber **202** of the housing **10'**. The assembled shafts (i.e. shafts with gears mounted thereon) are mounted on the bearing, shaft portions **320** being journalled in the openings **274, 276** of the bearing. The one-piece bearing **210** is then mounted on the assembled shafts, shaft portions **320** being journalled in the openings **224, 226** of the bearing. Thus, the one-piece bearings provide precise alignment of the shafts and maintain the shafts in parallel relation in the housing. The lid **16'** is then secured to the housing via the conventional fasteners **F'**.

[0062] Accordingly, the present invention provides a gear pump having powder metal components with distinct advantages over the conventional components. In addition to the uniqueness of using powdered metal technology to make the bearings **210** and **212**, the continuous configuration of the bearing provides a higher accuracy in alignment by avoidance of the connecting separate bearing **80, 82** of the prior art. Thus, it is possible to precisely align the center axes of the openings for the bearings.

[0063] Moreover, the one-piece bearings **210, 212** in the preferred embodiment are a straight line design, *i.e.,* across the top and bottom surfaces of the bearing, whereas, the conventional bearing **80, 82**, when connected, have a figure eight design. By incorporating the straight line design, a more precise and easier alignment of the bearings **210, 212** into the chamber **200** of the housing **10'** can be achieved compared to the conventional figure eight design.

[0064] The one-piece bearing **210, 212** also allows for greater control of the openings in centerline-to-centerline positioning where the control may be as much as

plus or minus one hundredth millimeter. However, the two-piece figure of eight design generally needs to be machine leveled to obtain that exactness, which is very time consuming. Further, since the separate bearings **80, 82** are connected, it is possible that separation of the two piece bearing may occur thereby not allowing functional operation. On the other hand, because the bearings **210, 212** have a unitary design, they cannot separate during operation of the gear pump **GP'**.

[0065] Cost benefits over the above described prior art design approach as compared to the low cost powdered metal design approach of the present application are set forth, in one example, in the following Table:

Feature	Conventional Design Approach	Low Cost Powder Metal (P/M) Design Approach
Gear	Gear and journal one piece fabrication	Gear blank and journal formed separately
Gear Teeth	Rough machined individually and final ground. Part inspection required. High Cost (about $800-$2500 per set).	Precision Carbide Tooling fabricated once, net shape formed, millions can be pressed without changing the tooling. Random sampling is required. High initial tooling cost but very low formed piece part cost (approximately $25-$30 each).
Gear Journal	Cut from a circular bar stock together with the gear. Both sides of journal size to be matched precisely. Integrated with gear, one piece construction.	Separated center-less ground. One journal, no matching problem. Key way is needed to drive the gear blank. Retaining rings to position the gear blank (approximately $25-$30 each).
Gear Width Matching	Matching to about .0002 inch, large pool of inventory is required for matching. Parallel to within about .0002 inch.	Dozen can be ground to the same height at once, no matching is required. Two sides will be automatically parallel.
Thrust Face Finish	Special super finishing operation.	Not required, as ground.
Deburring	Required, time consuming.	Tumble finish, a very simple

Feature	Conventional Design Approach	Low Cost Powder Metal (P/M) Design Approach
		operation.
Drive	Splined shaft, costly.	Hex Drive, low cost.
Total Cost	Very high	approximately 20% of conventional cost
Pressurized Bearing	Two separated parts	One piece construction
Drive Bearing	Fabricated individually. Final lapping at pump assembly. High precision machining required.	Designed for Powdered Metal application. One single piece. Net shape bronze powdered metal. Minimum machining required. One time initial tooling cost, very low per piece formed part cost (approximately \$3.00-\$5.00 each).
Driven Bearing	Fabricated individually, different from drive bearing. Final lapping at pump assembly. Relatively high cost.	
Loading Spring	Generally 12 for pressurized bearings	One
Fixed Bearing	Two fixed and two pressurized	One piece construction
Drive	Fabricated individually. Final lapping at pump assembly	One single piece. Net shape bronze powdered metal. Minimum machining is required. No matching is needed. One time initial tooling cost, very low per piece formed part cost. (approximately \$2.00-\$4.00 each).
Driven	Fabricated individually, different from drive bearing. Matching in height is required. Final lapping at pump assembly. Relatively high cost.	
Total Cost	High	approximately 25% of conventional design.
Drive Shaft	Input and Output splines	Hex shaft cut from standard stock
Total Cost	High	approximately 10% of conventional design.
Total Gear Pump Ass'y Cost	Very High	approximately 30%-40% of the conventional design

[0066] It is to be understood the above percentages and dollar figures are simply estimates and the values may, depending on the implementation, be different from those cited.

[0067] Accordingly, using powder metal to manufacture components for the gear pump **GP'** result in a much-improved manufacturing cost structure for gear pump fabrication and assembly. This is true since the gears, bearings and shafts constitute the majority of the fuel pump components.

[0068] The exemplary embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.